23 October 1962

MEMORANDUM FOR: Chief, Technical Plans and Development Staff

THROUGH : Chief, Technical Development Branch

SUBJECT : Staff Study - Projection Lens to Meet Present and Future Requirements

PROBLEM

1. There exists a requirement for a family of high quality projection lenses for enlargers and screening viewers.

FACTORS BEARING ON THE PROBLEM

2. Facts

A. From the beginning the art/science of lens design has utilized formulae based on the spherical surface almost exclusively. This is especially true in refractive type lenses as are those used on enlargers and projectors.

B. All lenses, particularly those of large aperture and of reasonable half-angle (15 degrees or larger), are burdened with the gamut of characteristic aberrations; they are astigmatism, coma lateral and axial color, spherical and field curvature to mention the most important. These aberrations are reduced by manipulating the index of refraction and dispersion of the optical glasses used in the different elements, the curvature of the surfaces and the spacing of the elements. No lens utilizing the spherical surface design in its calculation can be "fully corrected" to relieve it of these aberrations.

C. A lens can be designed to be diffraction limited for the optical axis image and for images falling as much as 5-7 degrees off axis. (See definitions for diffraction limit criteria). The inability to fully correct the inherent aberrations still makes this achievement difficult requiring numerous glass elements both cemented and air spaced. With the increase in numbers of elements, particularly air spaced, the light transmitted by the lens is significantly reduced. The ability to achieve the diffraction limit further off the optical axis is out of the question following present design criteria.

D. As far back as 1638, Descartes disclosed the geometrical design of a single element lens free from spherical aberration. The description had one surface a portion of an ellipse and the other surface was spherical with its center of curvature at one of the foci of the ellipse. The ellipse together with the parabola and the hyperbola are simple examples of what may be described as aspheric or nonspherical surfaces of revolution each having particular properties when used as refracting or reflecting surfaces. The reason for not designing lenses utilizing aspheric surfaces since the original by descartes has been the insurmountable mechanical problem of grinding, polishing and retaining the extremely high degree of accuracy required. Since World War II tremendous strides have been made in the lens grinding and polishing craft in the realm of generating the nonspherical surface to the point where some lenses in which one of the surfaces is aspheric are in commercial production. Previously such elements with the nonspherical surface were hand made; the economics of production precluded their use except in special cases.

3. Definition

The criteria for the diffraction limit is a function of the wavelength of light and the physical diameter or lens aperture, the limit being the diffraction pattern image of a point light source formed by the lens. This diffraction pattern is better known as the Airy disc.

DISCUSSION

4. The state of the art in lens design is at a point where one or more aspheric surfaces can be incorporated in a lens design to more nearly achieve a 'fully corrected' lens. It is to a point where economically it is feasible to consider designing a lens with all surfaces aspherized. By following this philosophy the number of elements required can be reduced by as much as 50 percent, light transmission increased by at least the same amount, come aberrations eliminated and others reduced to a bare minimum, the diffraction limit extended across very nearly the whole angular coverage and the angular coverage increased.

5. The lens under consideration would be of aperture of f/2, diffraction limited to at least 20 degrees off axis, diffraction limit resolution on axis of 845 l/mm for 486 mu, F line Hydrogen, and at 20 degrees 790 l/mm, a T-stop of 2.25 which means that theoretically 94 percent of the light will be transmitted, and it would have at least a 30 degree half angle.

6. This family of lenses would be used to retrofit enlargers and screening viewers now in use and would be a specific requirement for all future instruments.

7. This lens would be able to handle material resolutions up to 250 l/mm with only a 5 l/mm loss. This ability should satisfy future requirements for at least the next several years.

CONCLUSIONS

8. A major obstacle in the terminal quality of the product to be exploited by a screening viewer or projection enlarger is the quality of the lens. Significant improvements in this area of lenses will significantly improve the exploitation job, whether it be the interpretation of a screened image or a print.

ACTION RECOMMENDED

9. Authority be granted to pursue an advanced projection lens design.

10. Authority and procedure determined whereby the technical monitor can solicit advice and technical services of an authority in the area of lens design prior to soliciting proposals. Specifically the authority would be [redacted] 25

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